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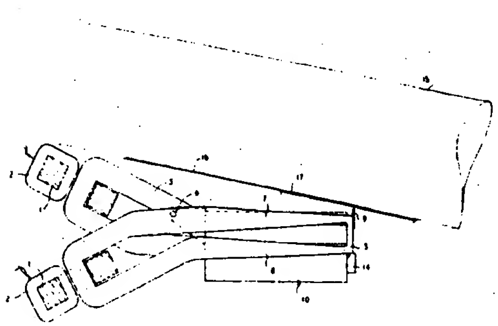
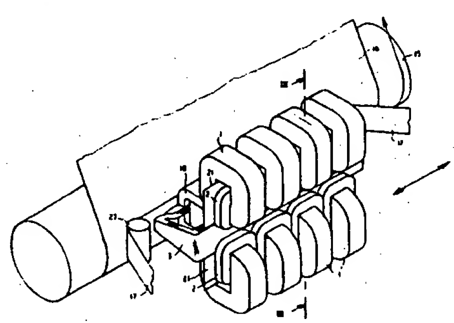
(54) Print mechanism for use in printing apparatus and printing apparatus including such mechanisms.

(57) A mechanism for a matrix printer has a robust single turn closed loop transformer secondary winding (3) as the moving part for driving a print stylus (9) into and out of a print position. Each secondary winding (3) threads a transformer core (1) on which is wound a multiturn primary winding (2). A stack of such secondary windings (3), arranged with print styli (9) in a closely spaced print row across the stack are supported in a static magnetic field produced by a magnetic assembly (10). Energisation of a primary winding (2) induces a large current flow in its secondary winding (3) which reacts with the field to drive the associated print stylus (9) into the print position. In one embodiment, the stack of secondary windings (3) are all mounted on a single pivot (6) and each swings about the pivot (6) as a whole upon energisation of its associated primary winding (2). In another embodiment each secondary loop of the stack is formed so as to be elastically deformable whereby a portion of the loop carrying the stylus is deflected into the print position upon energisation of its associated primary winding.





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PRINT MECHANISM FOR USE IN PRINTING APPARATUS AND PRINTING APPARATUS INCLUDING SUCH MECHANISMS

The invention relates to printing apparatus and in particular to a print mechanism for such apparatus.

Wire printers are well known and comprise for example a plurality of print wires each movable longitudinally in a respective guide tube in the print head. The guide tubes are grouped together at one end to form a print matrix or print line and located at a print position so that selective movements of the wires can be used to effect printing of selected characters, or parts of characters. Thus, in one form of wire printer, print wires are arranged in a row in a print head and the paper is moved in a direction perpendicular to the direction of the row of print wires. A character is printed by the correct selection and the timed actuation of the print wires synchronised with the movement of the paper. In the matrix type of wire printer, all of the print wires required for a given character are selected simultaneously from the matrix, and all portions of a character are printed at once. Alternatively, in another form of wire printer, the paper is moved intermittently in a vertical direction with the print head incrementally or continuously moved horizontally across the paper selectively controlled to print one line at a time whilst the paper is stationary.

Electromagnetic drivers or actuators forming part of the print mechanisms are energised to actuate each wire as needed to form the desired character. The actuators generally comprise an electromagnet having an armature fastened to its associated wire, energisation of which produces longitudinal movement of the wire in its guide. Further details of such a matrix print mechanism are to be found, for example, in United Kingdom Patent Specification No. 1,305,252.

The principle limitation of this type of matrix print mechanism is the maximum repetition rate at which the print wire can be fired at the paper in a controlled way. Firstly, the maximum acceleration of the wire is limited by the ratio of the applied force to the mass of the moving parts. This ratio is bounded by the fact that there is a limit to the energy that can be imparted to such an assembly by the magnetic circuit without unacceptable increase in heat or even the occurrence of physical distortion. Secondly, the wire, having been fired, bounces off the platten and returns to its original location retaining a significant proportion of the energy imparted to it. This energy must be dissipated and the part brought to rest before it can be fired again, or resonant conditions may be set up. The problem is alleviated to some extent by the use of return springs and mechanical dampers. Finally, the build-up of current in the energising winding is delayed by the inductance of the winding and a further limitation in speed is imposed.

According to the invention, a print mechanism comprises a plurality of print elements each of which is selectively movable between a retracted non-print position and an extended print position by means of individually energisable actuators, characterised in that each actuator comprises a transformer core having a primary winding, a closed loop

secondary winding, and means for generating a static magnetic field across a portion of the secondary winding, the direction of the field with respect to the secondary winding being such that, in operation, it reacts with secondary current induced in said winding as a result of energisation of the associated primary winding to apply a force on said portion in a predetermined direction, the secondary windings being constructed and arranged so that at least said portions are free to move under the influence of the applied forces, each print element being individually connected one to each of said portions of said secondary windings whereby movement of said portions causes corresponding movement of the associated print elements between retracted and extended positions.

According to one feature of the invention, the secondary winding is in the form of a coil mounted for limited angular movement about a pivot, the direction of the applied magnetic field across a portion of the coil being such that, in the presence of induced secondary current, movement of the coil as a whole is produced about the pivot.

According to another feature of the invention, the secondary winding is in the form of a self-supporting single conductive loop, the construction of the loop being such that a portion of the loop is elastically deformable in the plane of the loop, the magnetic field being applied across said portion in a direction such that in the presence of induced secondary current of a predetermined direction in said loop, said portion is deflected from a stable rest position to an unstable deflected position.

In order that the invention may be fully understood, preferred embodiments thereof will now be described by way of

example, with reference to the accompanying drawings, in which:

Figure 1 shows a schematic representation of an electromagnetic actuator incorporated in the present invention;

Figure 2 shows a plan view of one form of print mechanism according to the invention;

Figure 3 shows a sectional view along line I-I in Figure 2;

Figure 4 shows a sectional view along line II-II in Figure 2;

Figure 5 shows an isometric view of another form of print mechanism according to the invention;

Figure 6 shows a sectional view along line III-III in Figure 5;

Figure 7 shows a single secondary loop forming part of the mechanism shown in Figure 5 and Figure 6;

Figure 8 shows a stack of secondary loops forming part of the mechanism shown in Figure 5 and Figure 6; and

Figure 9 shows various graphs to illustrate the operation of the various mechanisms according to the invention.

Wherever possible, in the description to follow, the same reference numeral is used to identify the same part in the various diagrams.

The principle of operation of the actuator incorporated in the print mechanism according to the present invention, is shown in the schematic diagram of Figure 1. Here a transformer core 1 of soft magnetic material carries a multi-turn primary winding 2 and a single turn secondary winding 3. Although the secondary winding may have more than one turn, the embodiments to be described utilise single turn secondaries of fairly robust formerless construction. The assembly of magnetic core 1 and windings 2 and 3 behave as a conventional transformer and may be analysed and designed as is well known in the transformer art. Thus, application of current Ip to primary winding 2 generates a changing magnetic field in the core 1 which in turn induces current Is in secondary winding 3 by transformer action. If now, a magnetic field, represented by arrows 4, is applied across one limb of the secondary winding 3, then, with secondary current Is flowing in the direction shown, the limb of the winding 3 experiences a force tending to move it in the direction of arrow 5. Reversal of direction of primary current Ip results in reversal of the applied force thereby tending to move the winding in the opposite direction.

By mounting winding 3 for rotation about a pivotal axis disposed at right angles to the plane of the coil, and situated at one end of the aforesaid limb (for example, in the vicinity of the transformer core), movement of the secondary coil about this axis can be controlled by application of primary current Ip to the primary winding 2. A hard print stylus attached to the moving part of the secondary coil or loop can thus be controlled for striking a ribbon/paper/platten combination to produce a print mark on the paper in the usual way. Alternatively, if the secondary winding 3 is fixed, but elastically deformable so that the limb across which the magnetic field is applied is flexible

or deflectable, then application of primary current Ip to the primary winding produces movement of the limb in a direction determined by the direction of applied primary current. In this case, printing can be achieved by means of a print stylus attached to the flexible or deflectable part of the secondary limb. Both these techniques are employed in the embodiments described below of inductively driven print mechanisms. Clearly, however, any movement of the secondary loop whether by rotation about one axis or another, deformation of the loop itself or linear motion of the loop can be used to move a print element into and out of a print position. The print elements also may take any of several forms. For example, as in the embodiments to be described, print elements are in the form of short styli or 'anvils' carried by the secondary loops themselves. Alternatively, they may be in the form of extended print wires which are connected for driving purposes to the secondary loops but separately supported at the other end in a print head.

Figures 2, 3 and 4 show various views of a print head mechanism in which each of a row of closely spaced print styli or 'anvils' is controlled by an individually driven pivoted loop arrangement. Figures 5 and 6 show two views of a print head mechanism in which each print stylus or 'anvil' is controlled by an individually driven flexible or deflectable arrangement in which the secondary loop is elastically deformed. Figures 7 and 8 show details of the mechanism shown in Figures 5 and 6.

The first embodiment of the print mechanism is shown in plan view in Figure 2; as a section along line I-I in Figure 3, and a further section along line II-II in Figure 4. From these figures, the print head is seen to comprise a number (in this case eight) of secondary loops 3, each formed from a

thin aluminium sheet, or other suitable material, stacked together and mounted on a common pivot 6. On one side of the pivot 6, the loops each have two elongated limbs 7 and 8 and are closely stacked parallel to each other. Each limb 7 carries a stylus 9 of hard material suitable for performing print operations on a ribbon/paper combination. The styli on the secondary loops together form a closely spaced print row as required in the wire printer art for performing printing operations. The secondary loops are free to rotate independently of each other through a small angle about pivot 6. Thin layers of wear-resistant material such as polyimide (not shown in the figures) insulate the loops from each other and provide lubrication. Alternatively insulation may be provided by an anodised layer on the aluminium loops.

In order to provide sufficient space for individual transformer cores 1 to thread each secondary winding, the loops are fanned out in two planes at right angles to each other on the side of the pivot remote from the print styli 9. Thus, as shown in the sectional view of Figure 3, pairs of loops are fanned out, or bent in opposite directions, with respect to the longitudinal axis of pivot 6. These pairs of secondary loops are additionally fanned out in a plane at right angles to the plane of the bends as shown in the plan view of the print head mechanism shown in Figure 2. The relative disposition of the individual secondary loops 3 and associated transformer cores 1 is further illustrated in the sectional view of Figure 4.

Each transformer core 1 carries a multi-turn primary winding 2, which when energised induces a large current flow in its associated secondary loop 3. A permanent magnet structure 10 (shown generally in Figures 2 and 3 and in more detail in Figure 4) mounted on the opposite side of the pivot

6 from the transformer cores 1 provides a large magnetic field across the closely spaced parallel limbs 7 and 8 of all the secondary loops 3. More specifically, as shown in Figure 4, the magnet structure consists of two bar magnets 11 having pole-pieces 12 and 13 arranged to define two magnetic flux gaps in which the two closely stacked groups of elongated limbs 7 and 8 of the secondary loops are respectively located. The magnetic fields across the gap defined by pole pieces 12, containing secondary limbs 7, and the gap defined by pole-pieces 13, containing secondary limbs 8, co-act additively with the forward and reverse current in the limbs to cause a torque to be exerted on those loops in which secondary current is flowing. Consequent rotation of these secondary loops about pivot 6 moves the associated print styli towards and away from a print position. Sufficient clearance between transformer cores 1 and secondary windings 3 permit movement of the styli for printing to occur. In addition a rest position for the loops is provided by a stop 14 (shown only in Figure 3) of resilient material. A return spring (not shown) may be fitted to each secondary loop to hold them against the stop 14 when not being energised. However, as will be described later with reference to Figure 9, this particular invention enables the entire movement of print elements into and out of the print position, and the restoration of elements to the rest position to be entirely controlled electrically by appropriate energisation of the primary windings.

In use, the print head mechanism is mounted, as shown in Figure 3, with the row of print styli 9 adjacent and aligned at right angles to the longitudinal axis of a print platten 15 over which paper 16 to receive print is fed. A ribbon feed mechanism (not shown) increments an inked ribbon 17 interposed between the print styli 9 and paper in the usual manner.

The operation of this print head mechanism is as described in general previously. Thus, by selective energisation of primary windings 2, any print stylus 9 or combination of print styli, can be caused to impact the interposed ribbon 17 and produce corresponding printed marks on paper 16 carried by platten 15. Relative movement between paper and print head necessary to print in rows may be achieved by any of a number of well known mechanisms. For example, the print head mechanism may be held stationary and the platten carrying the paper moved past in the direction of its longitudinal axis with incremental line shifts between rows as required. Alternatively, the platten may be fixed and the print head mechanism itself moved in a print carriage along the length of the platten. The print carriage may support the ribbon feed mechanism, or this may be provided as an independent mechanism. These various arrangements are all well known in the printer art and since they form no part of the present invention, except as a vehicle in which it is used, they are not described in this specification.

The second embodiment of the invention is shown in perspective view in Figure 5 and in section along line III-III in Figure 6. From these figures, the print head mechanism is seen to comprise, as in the previous embodiment, a number (in this case eight) of secondary loops 3 each formed from a thin aluminium sheet or other suitable material, and having an associated transformer core 1 carrying a secondary winding 2. In this embodiment, the print action relies on selective elastic deformation of the secondary loops 3 rather than their rotation about a pivot. The secondary loops 3 are closely stacked together and each carries a print stylus 9 positioned midway along a specially formed flexible limb of the loop. Figure 7 shows a single secondary loop 3 having a flat main structural limb 18, two flat side portions 19, and

a deflectable limb 20 carrying a print stylus 9 at its mid-point. The limb 20 is provided with two ninety degree twists, one at each end of the limb, between it and the two side portions 19 so that the width of the limb lies in the plane of the print stylus 9 and of the coil. The width of the loop is also reduced along the limb 20 to make it more flexible, but maintained relatively large elsewhere in order to reduce electrical resistance. Rotation of the plane of limb 20 through ninety degrees in this manner provides increased flexibility of the loop and enables a number of such loops (in this case eight) to be closely stacked together as shown in Figure 8. Clearly, in order for this to be possible, the loops must become progressively larger by small amounts from inside to outside the stack. A crank 21 is provided in the main limb 18 of each loop for accommodating a transformer core 1. Each crank is progressively off-set from its neighbour to provide sufficient space for all the transformer cores 1. In this embodiment, the cranks provide equally spaced transformer apertures 22 along each side of the stack of loops. The loops are electrically insulated from each other either by an anodised coating or by an insulating layer of wear resistant material such as polyimide which also acts as a lubricant between the loops in the stack.

The transformer cores 1 are shown in Figure 5 threaded through transformer apertures 22, each uniquely associated with a secondary loop in the stack. Each transformer core 1 carries a multi-turn primary winding 2 which when energised induces a large current flow in its associated secondary winding 3. A permanent magnet structure 10 (shown generally in Figure 5 and in more detail in Figure 6) provides a large magnetic field across the closely spaced deflectable limbs 20 of the secondary loops. More specifically (as shown in

Figure 6), the magnet structure consists of a single bar magnet 23 having pole-pieces 24 arranged to define a magnetic flux gap in which the closely stacked group of deflectable limbs 20 of the secondary loops are located. The direction of flux across the gap is such that it co-acts with secondary current in a loop 3 to generate a torque in the loop which causes deflection of the limb 20 and movement of the print stylus 9 towards and away from a print position. A resilient stop 25 (Figure 6) provides a rest position for the secondary loops. In this embodiment, the elasticity of the loops is sufficient to hold them against the stop 14 when they are not being energised.

In use, the print head mechanism is mounted on a stationary or movable carriage 26 (part shown in Figure 6) as in the previous embodiment, the row of print styli 9 being adjacent and aligned at right angles to the longitudinal axis of a print platten 15 over which paper 16 is fed. A ribbon feed mechanism (not shown) increments an inked ribbon 17 interposed between print styli 9 and paper 16. One ink ribbon roller 27 is visible in Figure 5. Selective energisation of primary windings 2 causes a print stylus 9 or any combination of print styli to impact the interposed ribbon 17 and produce corresponding printed marks on the paper 16.

Operation of the inductive impact print mechanisms subject of this invention is generally illustrated by reference to Figure 9 of the drawings which shows a graph of print stylus movement and the values of applied voltage, primary current Ip, secondary current Is throughout one cycle of motion of a print mechanism having pivoted secondary loops. For the first 200 microseconds, 10 volts is applied to the primary winding of a selected print stylus. The primary current Is builds up to a maximum of 4 amperes and a

secondary current Is of about 130 amperes is induced in the associated secondary loop. This large current co-acts with the applied magnetic field to move the print stylus towards the print position. The voltage is removed after being applied for 200 microseconds and the secondary loop contines its movement until the print stylus strikes the platten and rebounds therefrom. The print stylus typically moves 0.3 mm from its rest position to the platten. At 400 microseconds from the start of the cycle, the voltage is re-applied to arrest the motion of the secondary loop until at around 550 microseconds the loop is approaching its rest position once again with a small residual velocity. At this point, the applied voltage is reversed thereby holding the loop against its stop. Small rebounds of the loop occur. At 900 microseconds from the start of the cycle, the flux in the transformer core has decayed to zero and the reverse applied voltage can be removed or alternatively another cycle commenced.

Operation of print mechanisms of other construction according to the invention such as those having deformable secondary loops or other arrangements in which secondary loop movement is used to effect printing, generate waveforms of a similar nature. It should be noted however that the actual shape and values of the waveforms will change from mechanism to mechanism depending on the various parameters of the structures used. The described example with reference to Figure 9 has been included to show typically how the present mechanism is driven in a controlled manner during printing to improve the efficiency of the print operation.

As has already been mentioned, present print heads have performance limitations governed by the maximum repetition rate at which the print wires can be fired in a controlled

manner. The present invention shows an improvement of three fundamental limitations of present matrix heads.

1. The transformer construction provides physical separation between primary coil and the moving parts enabling the secondary coil to be physically larger than the equivalent solenoid operated print wire. Further, primary winding heat is isolated from the more sensitive moving parts permitting more power to be applied to the mechanism.

2. The rate at which current is built up in the secondary loop is very much higher than possible in a directly energised device since the working coil has only one turn (inductance is proportional to the square of the number of turns). From Figure 9 it is seen that secondary current is fully established in 100 microseconds whereas with solenoid operated print wires current is still increasing even at the end of the energised period (typically 400 microseconds).

3. The bi-directional nature of the driving forces in the mechanism of the present invention, and the ability to charge secondary current rapidly, enables the motion of the print elements to be controlled during both forward movement into the print position and return movement to the rest position without large rebounds from the stop. This is a significant improvement over state-of-the-art solenoid operated printers in which the magnetic force is always unidirectional and time constants are relatively large.

CLAIMS:

1. A print mechanism comprising a plurality of print elements each of which is selectively movable between a retracted non-print position and an extended print position by means of individually energisable actuators, characterised in that each actuator comprises a transformer core having a primary winding, a closed loop secondary winding, and means for generating a static magnetic field across a portion of the secondary winding, the direction of the field with respect to the secondary winding being such that, in operation, it reacts with secondary current induced in said winding as a result of energisation of the associated primary winding to apply a force on said portion in a predetermined direction, the secondary windings being constructed and arranged so that at least said portions are free to move under the influence of the applied forces, each print element being individually connected one to each of said portions of said secondary windings whereby movement of said portions causes corresponding movement of the associated print elements between retracted and extended positions.

2. A print mechanism as claimed in claim 1, in which each secondary winding is in the form of a coil mounted for limited angular movement about a pivot, the direction of the applied magnetic field across a portion of the coil being

such that, in the presence of induced secondary current, movement of the coil as a whole is produc d about the pivot.

3. A print mechanism as claimed in claim 2, in which the coil is a self-supporting single conducting loop of generally elongate form, constructed from thin sheet material so that the plane of the material lies in the plane of the loop, the loop being pivoted for limited movement about an axis at right angles to the plane of the material about a pivot provided along one side of the loop, said transformer cone linking the loop at one end, on one side of the pivot, and the print element attached to the loop at the other end on the opposite side of the pivot.

4. A print mechanism as claimed in claim 3, in which all secondary windings are mounted electrically insulated from each other for limited angular movement about a common pivot, the parts of the loops on said one side of the pivot being fanned out in order to accomodate said transformer cores, one on each loop, and maintained closely parallel to each other on said opposite side of the pivot, the print elements being in the form of print styli attached one to each secondary loop in a print row parallel to the pivot axis.

5. A print mechanism as claimed in claim 4, in which said static magnetic field is generated across corresponding portions of all secondary windings by a single magnetic structure constructed to apply a magnetic field of one sense across corresponding first portions of all the secondary windings and a magnetic field of opposite sense across corresponding second portions of all the secondary windings, the first and second portions being selected such that the resulting torque produced by secondary current flow in a selected secondary winding is additive.

6. A print mechanism as claimed in claim 1, in which the secondary winding is in the form of a self-supporting single conductive loop, the construction of the loop being such that at least a portion of the loop is elastically deformable in the plane of the loop, the magnetic field being applied across said portion in a direction such that in the presence of induced secondary current of a predetermined direction in said loop, said portion is deflected from a stable rest position to an unstable deflected position.

7. A print mechanism as claimed in claim 6, in which said self-supporting single conductive loop is of elongated rectangular shape constructed from thin sheet material, the sheet of material forming one long limb and two short side limbs of the rectangle lying in planes at right angles to the plane of the loop and the other long side being twisted at its ends with respect to the side limbs so that the sheet of material from which it is formed lies in the plane of the loop, this latter limb including said portion of the loop which carries a print stylus and in use is deflected between a stable rest position and an unstable deflected position.

8. A print mechanism as claimed in claim 7, in which a plurality of said loops of the same general shape, but of slightly different dimensions to enable the loops to be stacked together, are stacked together insulated from each other with the deflectable portions closely parallel to each other, and the print styli, one on each loop, aligned in a print row across the width of the stack, said other long side of each loop being supported one upon the other and each having a cranked portion defining an aperture between the crank and the remainder of the stack of loops for receiving a transformer core, the cranks being displaced from one loop to the next in order to provide sufficient space to accomodate

all the transformers, one on each loop and in which said static magnetic field is generated across corresponding deflectable portions of all the secondary windings by a single magnetic structure.

9. A print mechanism as claimed in claims 3, 4, 5, 7 or 8 in which the or each self-supporting single conductive loop is formed from anodised aluminium sheet provided with a wear resistant coating of polyimide.

10. Printing apparatus including a print mechanism as claimed in any one of the preceding claims mounted adjacent a print platten such that, with relative movement between print mechanism and platten, selective movements of said print elements from retracted to extended position can be used to print marks on paper carried by the platten and further including means for applying current pulses of a first predetermined polarity to selected primary windings of the print mechanism to cause movement of the associated print elements towards the platten, the magnitude of the pulses being sufficient to cause said elements to rebound from said platten, means for applying further pulses of the same polarity to said windings after the elements have rebounded from the platten, in order to retard but not stop said elements during their movement into the retracted position, and means for applying pulses of reverse polarity to said primary windings when said elements approach the retracted position to maintain the elements in the retracted position.

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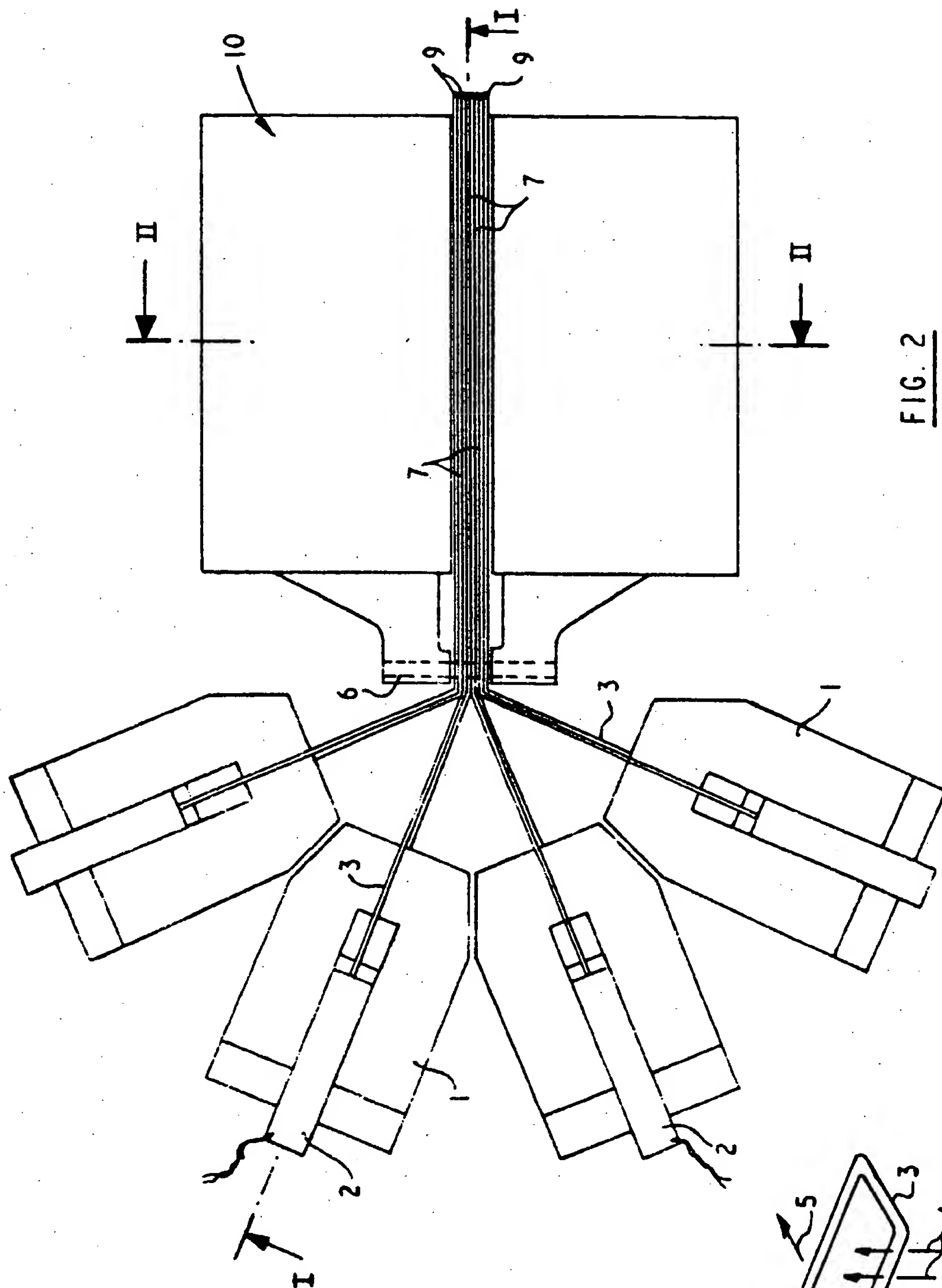

FIG. 2

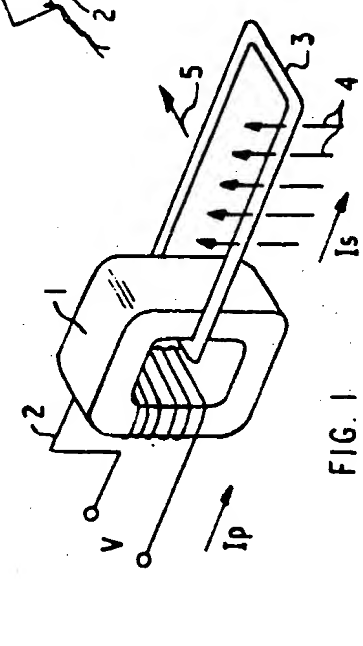

FIG. 1

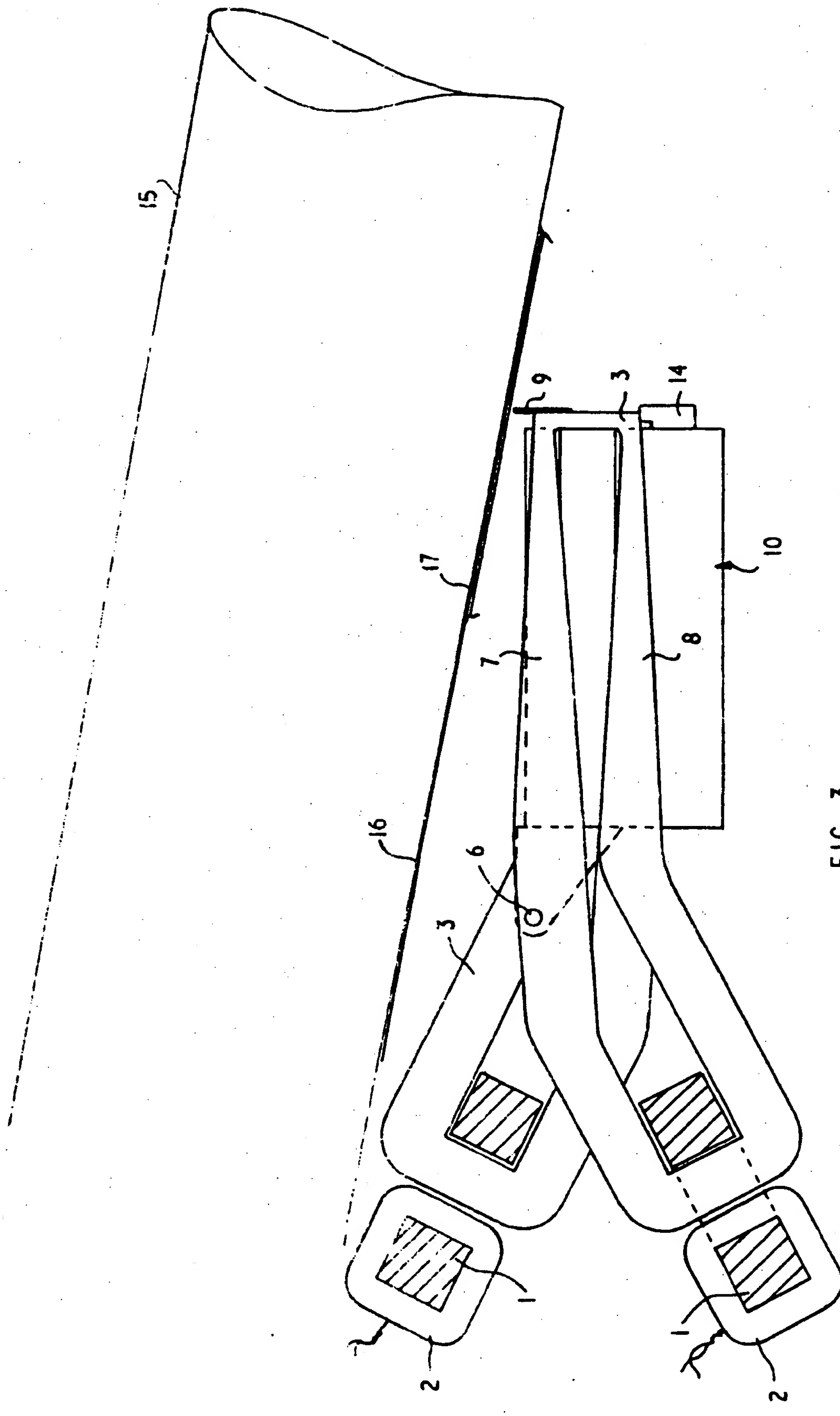

FIG 3

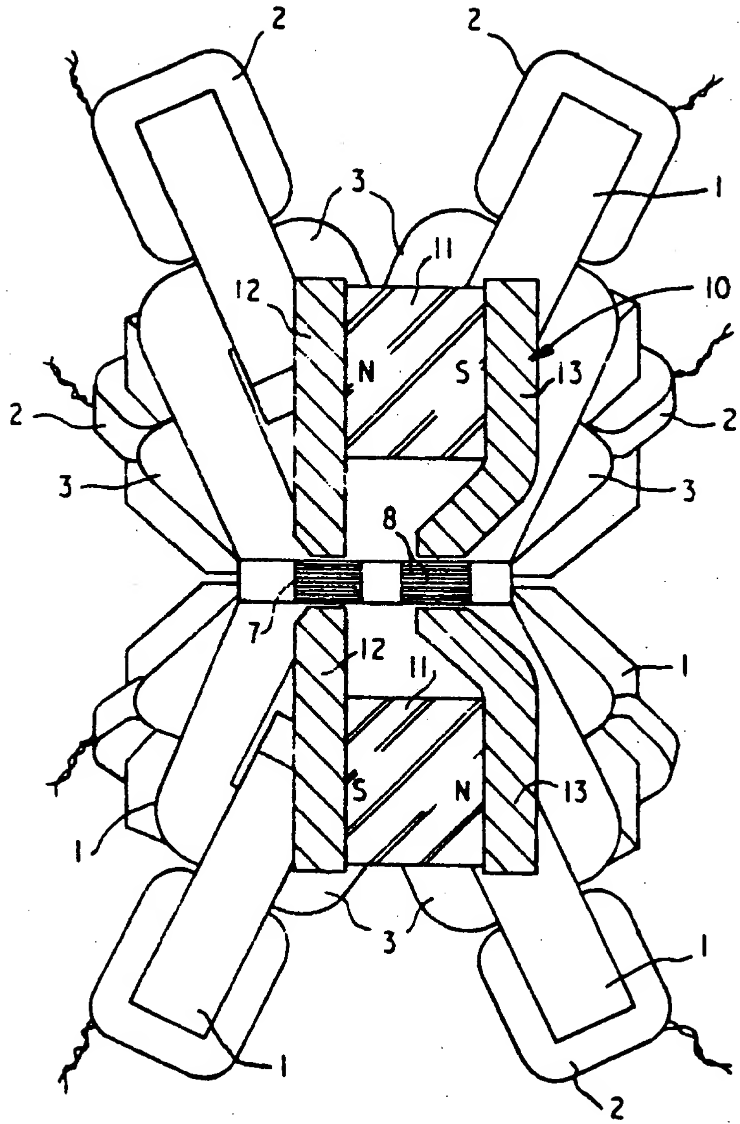

FIG. 4

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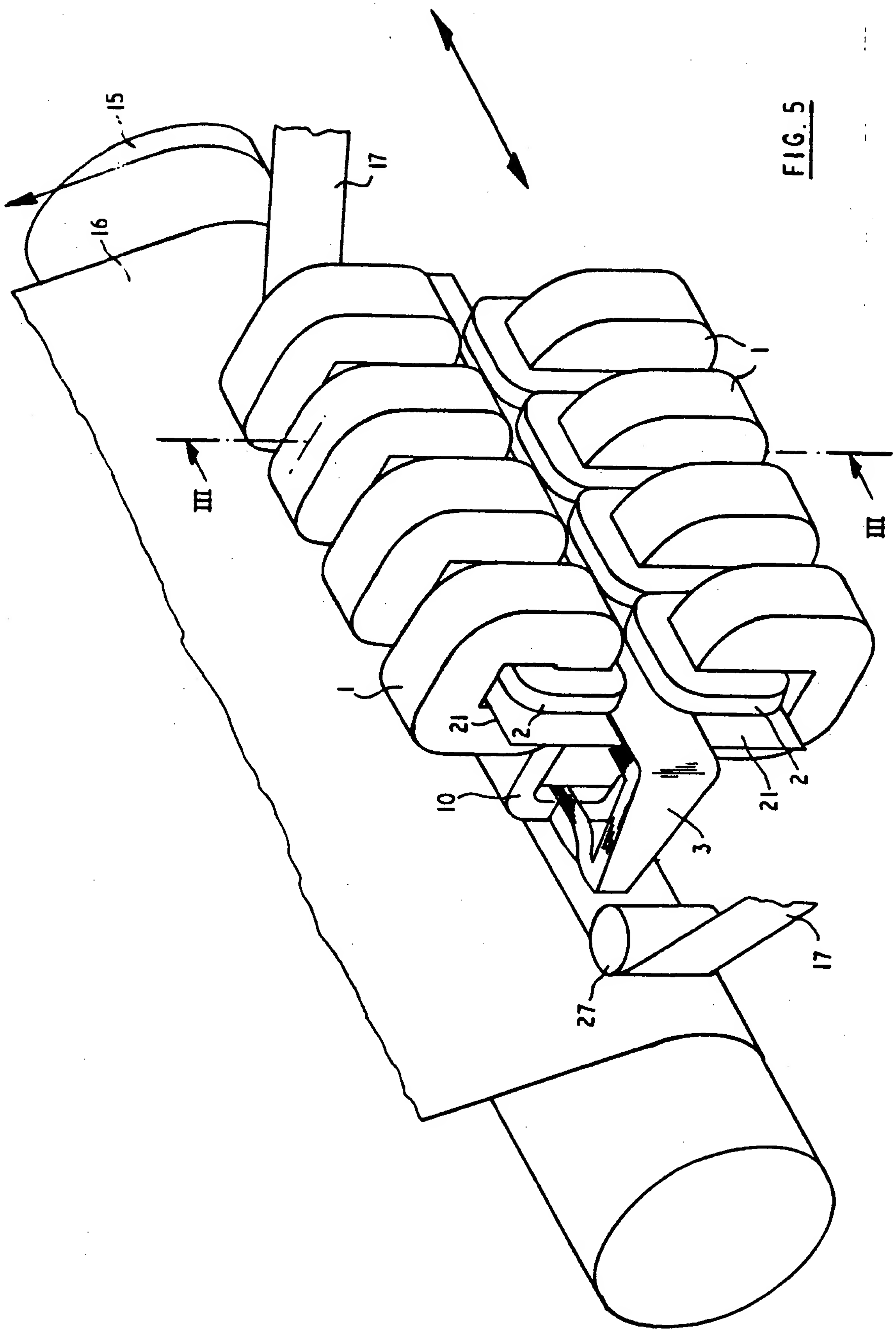


FIG. 5

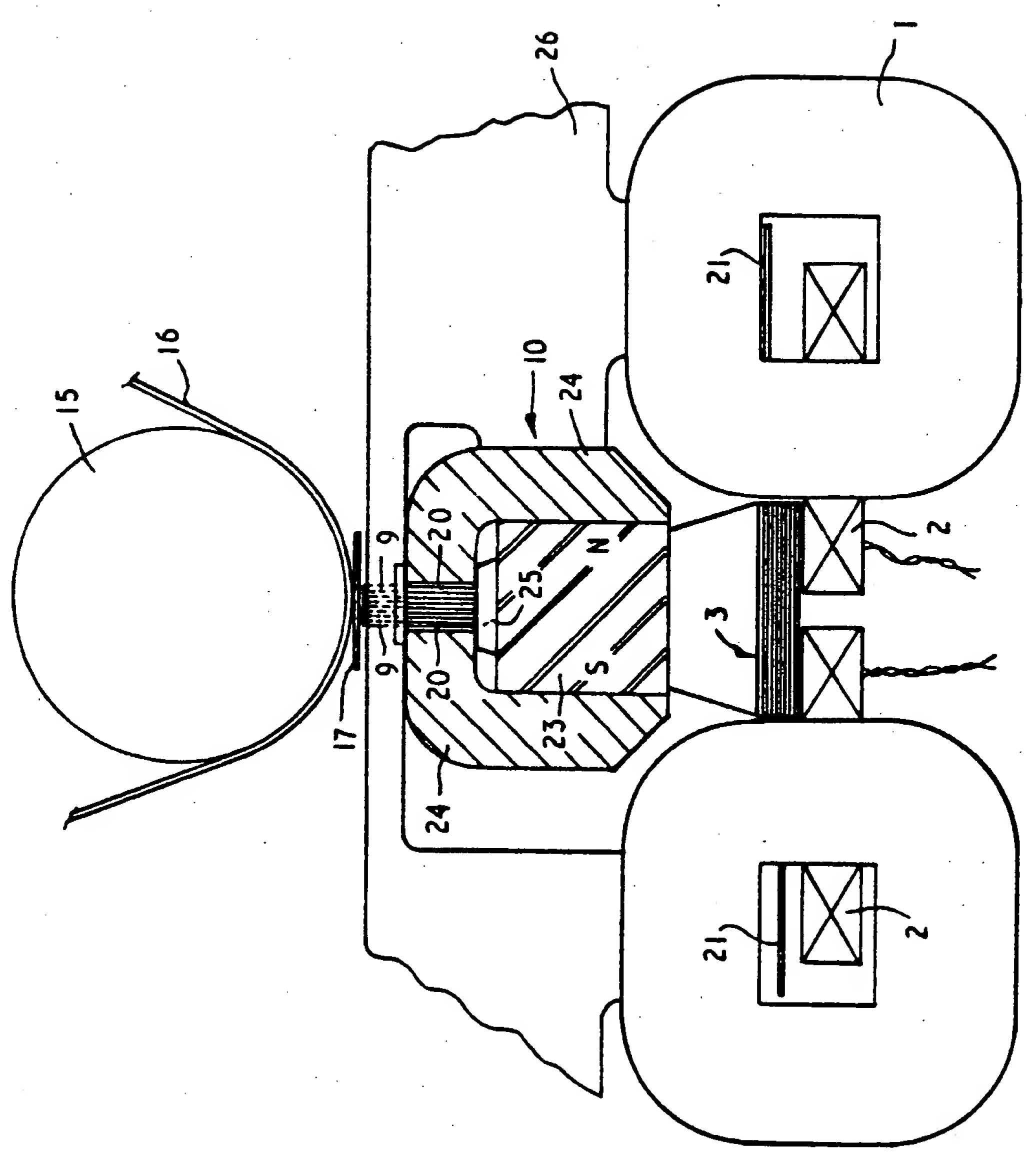


FIG. 6

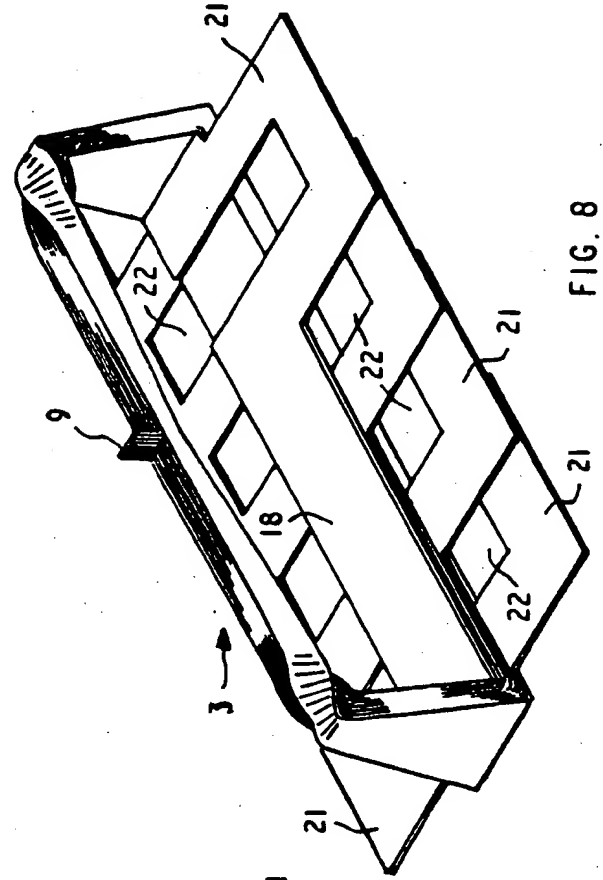


FIG. 8

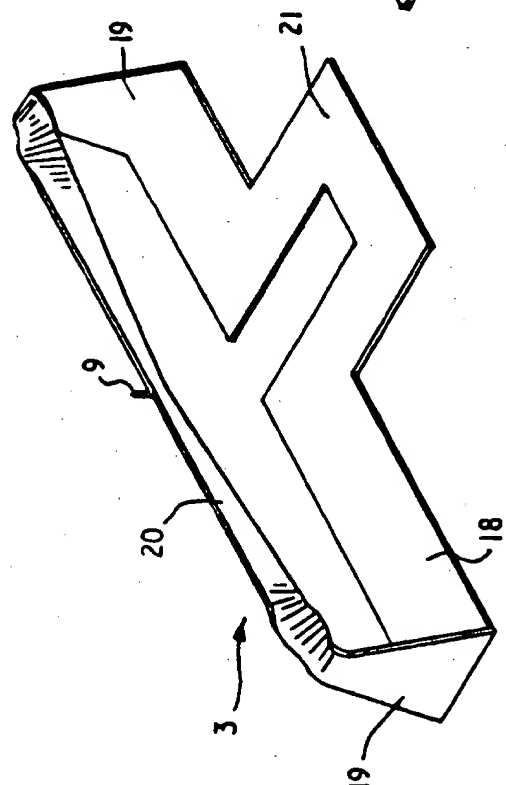
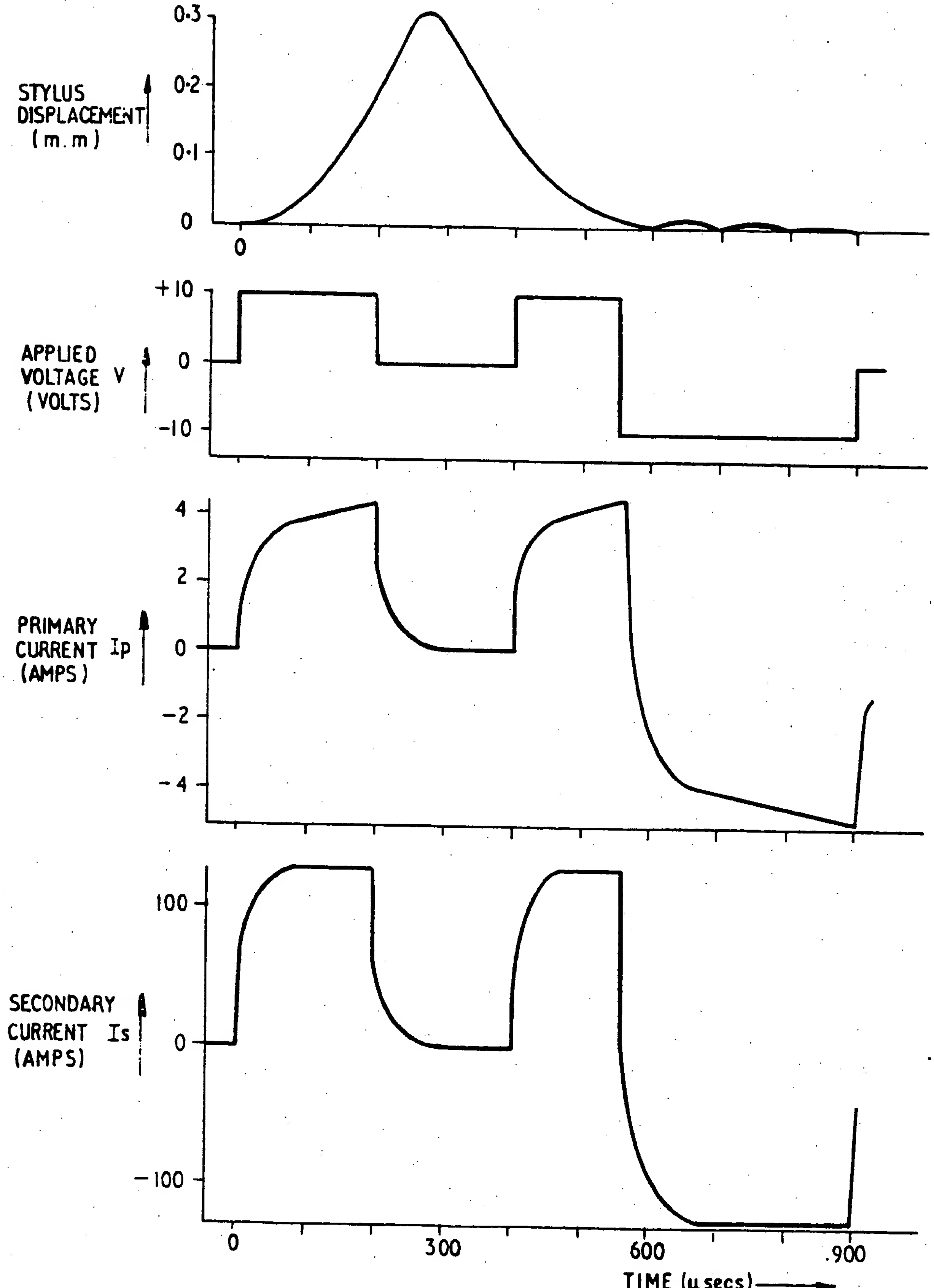


FIG. 7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TIME (μsecs)

FIG. 9

European Patent Office

EUROPEAN SEARCH REPORT

0006166

Application number

EP 79 101 704.9

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
X	IBM-Technical Disclosure Bulletin, Volume 13, Nr. 12, May 1971, New York D.E. RUTTER, SR. "Single-turn moving coil print magnet" page 3767 --	1
	GB - A - 1 149 699 (IBM) * fig. 1 * --	1
A	DE - A - 2 722 275 (GENERAL ELECTRIC) * complete document * --	
A	US - A - 3 285 166 (C.J. HELMS et al.) * complete document * ----	

CLASSIFICATION OF THE APPLICATION (Int. Cl.³)

B 41 J 3/12

TECHNICAL FIELDS SEARCHED (Int.Cl.³)

B 41 J 3/12
G 06 K 15/00

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	12-09-1979	ZOPF